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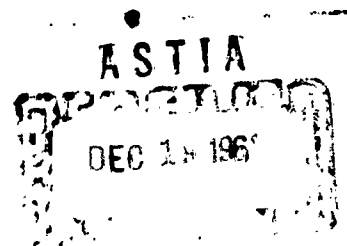
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BACKSCATTER SOUNDING DURING IONOSPHERIC STORMS

by
I. RANZI and P. DOMINICI

Scientific Note No. 5
May 15, 1961



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CENTRO RADIOELETTRICO SPERIMENTALE
«G. MARCONI» - ROMA

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CENTRO RADIOELETTRICO SPERIMENTALE "G.MARCONI"
ROME, ITALY

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SUMMARY

The results of the ionospheric sounding by ground backscatter carried out at Torrecchiaruccia (S. Marinella, Roma), during some severe ionospheric storms from August 1957 to February 1961, are briefly discussed. The advantages of the backscatter sounding in order to study the morphology of an ionospheric storm over a large area are put in evidence.

The observed displacement of the perturbed zone may be explained as the result of the superposition of the D_{st} and S_D storm components.

During an ionospheric storm, the echoes from the non disturbed zone show a stronger intensity and a wider extent than in normal conditions.

1 - Introduction.

The object of this work is to summarily investigate the possibilities of the ionospheric ground backscatter sounding to study ionospheric disturbances: to this purpose, the results of the b.s. soundings performed since August 1957 in the experimental station of Torrechiaruccia (S. Marinella; Roma; lat. 42.03°N; long. 11.83°E) of the CENTRO RADIO ELETTRICO SPERIMENTALE "GUGLIELMO MARCONI" (1), have been examined.

As it is well known (2), in the b.s. sounding, pulsed radio waves, radiated by a directional antenna, are reflected from an ionospheric layer towards the ground at some distance from the transmitting antenna, when the ionization conditions are favourable; owing to the ground irregularities, some energy is backscattered and, by running over its own going path again, it comes back to the antenna and produces the so-called "ionospheric ground backscattered echoes". When multiplying the velocity c of the light in vacuo by the half echo delay, we obtain the so-called "equivalent b.s. distance" D' ; in particular, when multiplying c by the half minimum echo delay (corresponding to the leading edge of the b.s. signal), we have the "minimum equivalent b.s. distance" d' . If f is the frequency of the emitted waves, f_o the critical frequency and h the height of the ionospheric reflecting zone, the skip distance d corresponding to the frequency f is a function of d' , f_o and h ; the rays geometry is such one that d may be determined with a sufficient accuracy starting from d' , even if f_o and h are not exactly known (3; 4). It is evident that f is the d -MUF concerning the reflecting ionospheric zone (for instance, the F2- d -MUF) along the direction to which the antenna is pointed. If the antenna is made continuously rotating in an horizontal plane and the receiver (by using the same antenna) is connected with a suitable photographic recorder, we obtain the azimuthal distribution of d .

The soundings carried out at Torrechiaruccia were performed according to this technique, the working frequencies being so high to be reflected by the diurnal F zone. They have been systematically effected during the I.G.Y. (from August 23, 1957 to January 31, 1958 on 18.6 Mc/s; from February 1, 1958 to January 31, 1959 on 22.3 Mc/s); after the I.G.Y., they were no more performed in a regular way, owing to some particular researches on the mechanism of the ground backscatter.

The "regular" soundings were performed with a sounder having the following characteristics:

pulse length: 1000-700 microsec.

pulse repetition frequency: 16.6 pulses per sec.

radio frequency: 18.6 or 22.3 Mc/s.

r.f. power: 2-4 kW peak of antenna input.

transmitting-receiving antenna: four-element horizontal Yagi, with effective half-power beam of about 60°, rotating at a speed of 2 revolutions per minute.

recorder: c.r. oscilloscope with a 35 mm camera; rectangular coordinates presentation;

distance marks every 400 km; direction mark to South (Fig. 1).



Fig. 1 - Film record of a b.s. sounding on 22.3 Mc/s (January 10, 1961; 1200 L.T.)

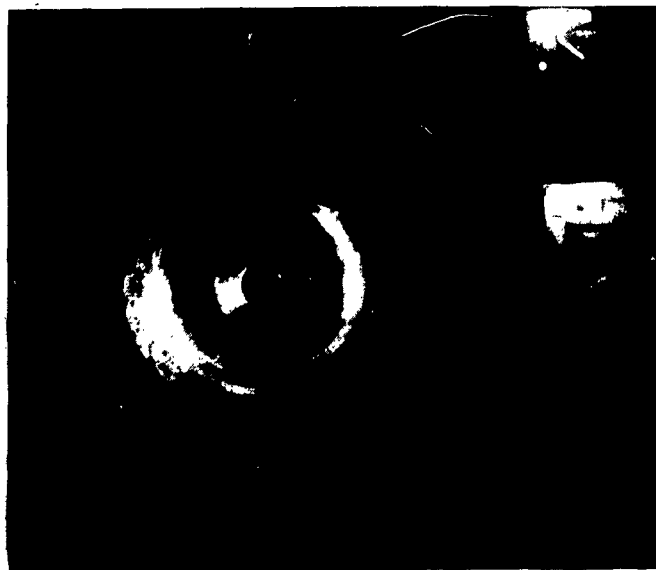


Fig. 2 - PPI record of a b.s. sounding on 18.6 Mc/s (April 12, 1961; 1013 L.T.)

PPI with a 16 mm movie camera; polar coordinates; distance marks every 500 km (Fig.2).

As it follows from the theory (3;4), the b.s. sounding with fixed frequency and variable direction is intrinsically unable to give, with sufficient accuracy, the value of f_o starting from the one of d' , if h is not known. However, by comparing the results of the b.s. sounding with the ones of the vertical sounding, we observe that the variations of f_o and h produce parallel variations of d' , which increases when f_o decreases and h increases, and decreases when f_o increases and h decreases. This method is, therefore, particularly suitable for studying the ionospheric storms, their course being characterized, as it is well known, by opposite variations of the critical frequency and of the height of the F region.

2 - Morphology of some ionospheric storms observed at Torrechiaruccia trough b.s. sounding.

The more disturbed periods were identified by considering the deviation of the values of d' in respect of the monthly median values; these deviations were compared with the analogous deviations of f_oF2 observed in some ionospheric stations and with the behaviour of the geomagnetic field. Once isolated in such a way, some of the strongest ionospheric storms were examined in full particulars.

As regards the morphology of the ionospheric storms, as they appear in the b.s. soundings, we must remark that if the sounding frequency f is high and the ionospheric disturbance is strong enough, the b.s. echoes via F coming from some particular directions may cease being received (that generally occurs when the skip distance becomes larger than 3000 km). This fact is, on one side, interesting as to point out the most perturbed directions; but, on the other side, it deprives us of any quantitative information on the ionospheric conditions in the perturbed area.

In the Fig.3 we reproduce, as an example, the "ionograms" of some soundings performed at Torrechiaruccia on 12th, 13th, 14th September 1957, on 18.6 Mc/s. These ionograms are a graphical transformation of the original records (Fig.1): the zones, where the echoes come from, are indicated in polar coordinates (equivalent distance in km; geographical azimuth), the pole of which corresponds to the sounding station; the time is the 15°E standard time. Whilst, under normal conditions, the b.s. echoes via F2 come from the whole horizon, the value of D' being between about 1400 and 2000 km, in some of these ionograms there are no echoes on a great deal of the horizon. It is to be remarked that, in some ionograms, echoes from about 800 km are also visible, these echoes being due to a b.s. via Es. or/and to a direct b.s. from auroral ionization.

In the Fig.4, we reproduce the behaviour of the deviation Δf_oF2 of f_oF2 from its monthly median value, during the period from 12th to 15th September at Churchill, Canada (about 6000 km

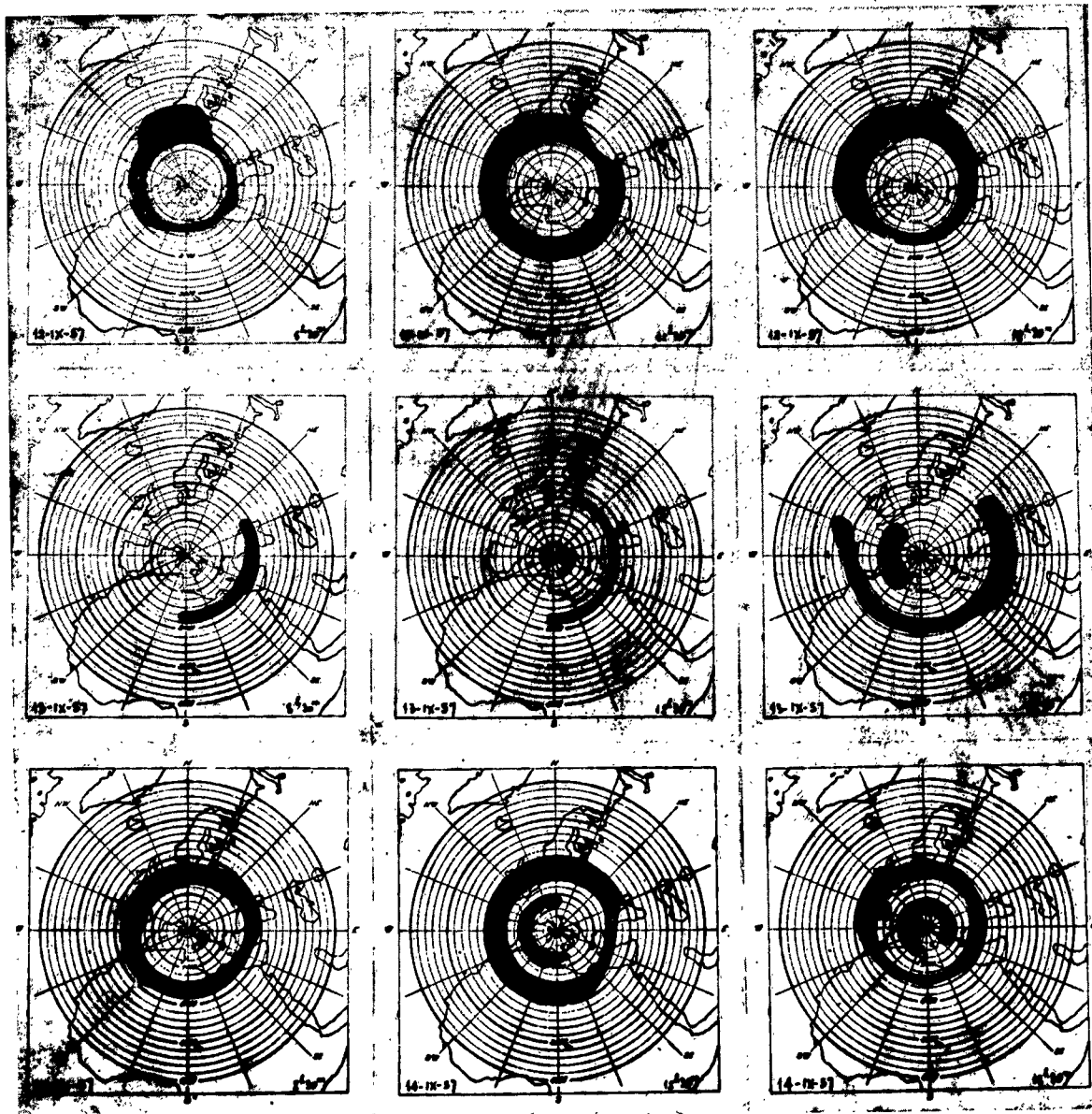


Fig. 3

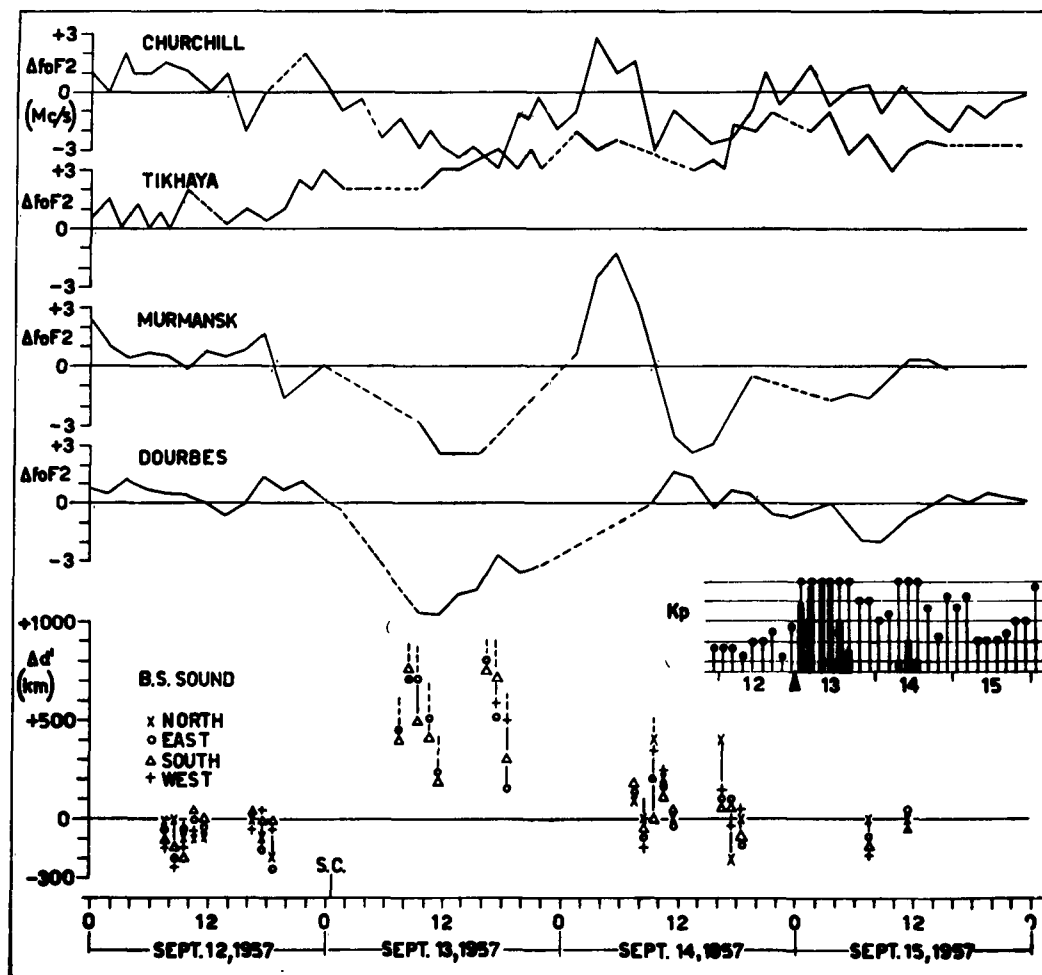


Fig. 4

from Torrechiaruccia in the direction NNW), Tikhaya, U.S.S.R. (4500 km, NNE), Murmansk, U.S.S.R. (3000 km, NNE), Dourbes, Belgium (1300 km, NNW) and of the deviation $\Delta d'$ of d' from its monthly median value in the four cardinal directions from Torrechiaruccia; it is even reproduced, with the usual symbols, the behaviour of the geomagnetic planetary three-hour range index Kp during those days. We observe that, during the night between the 12th and the 13th, a magnetic storm arose (S.C. at 00^h47^m G.M.T.); the maximum of the ionospheric storm at middle latitude occurred at midday on 13th; a moderate magnetic and ionospheric agitation lasted during the day 14th.

Whilst considering the Figs. 3 and 4, we notice the following main facts:

- (a) as it was to be expected, the storm gave rise to a general increase of the equivalent h.s. distances;
- (b) the disappearance of the echoes from North and from West during the main phase of the disturbance, shows that the storm affected mainly the direction NW (the anisotropy of the disturbance clearly appears in the increased dispersion of the value of d' in the different direction);
- (c) the disturbance appears to slowly move towards NE.

H.s. ionograms during other ionospheric storms are shown in the Fig. 5 (November 26-27, 1957; 18.6 Mc/s), in the Fig. 6 (July 7-10, 1958; 22.3 Mc/s) and in the Fig. 7 (November 14-17, 1960; 22.3 Mc/s). The Fig. 8 shows the ionograms on 22.3 Mc/s at 0900^h in the period between the 1st and the 12th September 1958, including a magnetic storm with S.C. at about 1000 G.M.T. of the day 3rd and a strong disturbance on 4th; we must remark the deep change of the echoes pattern from one day to another one.

In the Fig. 9 it is reproduced, as to the disturbance of the period of November 26-27, 1957, the behaviour of the ratio between actual and median values of foF2 at Dourbes, Belgium (1300 km, NNW) and at Moscow, U.S.S.R. (2200 km, NE), as well as of the ratio between median and actual values of d' in the four cardinal directions from Torrechiaruccia, and of the geomagnetic index Kp. If we consider this Figure and similar diagrams concerning other ionospheric storms, we come to conclusions, which are similar to the above ones concerning the storm of the period of September 12-14, 1957.

From a simple morphological point of view, we have to remark the following facts:

- (i) the zone concerning the maximum increase of skip distance during a storm lies approximately in the direction of the magnetic North; during the initial and the recovery phase, such a zone shows a tendency to move, according to the cases, towards West or towards East.
- (ii) the extent of the zone where the h.s. echoes come from, has a tendency to increase in the directions along which the skip distance recovers its normal value.

What we pointed out at (i), may be justified on the ground of what is known as to the morphology of the ionospheric storms at middle latitudes (5; 6).

The zone of the maximum increase of the skip distance during a storm appears to be

near the direction of the magnetic North, because the storm always develops its main phase near the magnetic Pole; the dependence of the course of the storm on the local time of the magnetic sudden commencement may explain the apparent displacement between NE and NW of this zone.

According to the schema proposed by D. F. Martyn (6) and today universally accepted, the variations of f_oF_2 , and also of $h'F_2$, during an ionospheric storm, come from the superposition of two disturbance waves, both rising within a short time from the magnetic S.C.: the storm-time variation (D_{st}) which is independent of the local time, and the disturbance day variation (S_D) which depends on the local time. As the S_D variation, at the middle magnetic latitudes, is of the same order of D_{st} variation (Fig. 10), the course of the storm remarkably depends on the local time of the commencement of the storm itself (Fig. 11). Consequently, for a station being located like Torrechiaruccia, the zone of the maximum of the disturbance appears to move with a period of about 24 hours, the movement being approximately towards NW in the a.m. hours, towards NE in the p.m. hours.

As to the above mentioned point (ii), the greater intensity and extent of the backscattered echoes coming from the less perturbed directions, may be referred to the fact that, during the disturbance, the structure of the ionosphere is more complex along these directions, where a rapid transition from disturbed to normal conditions occurs: the high horizontal gradients of ionization may produce "tilted-layer mode" of b.s. propagation. Such conditions are visible, for instance, at 0830^h on November 27, 1957 (Fig. 5), at 1200^h on July 7, 1958 (Fig. 6) and in several ionograms of the Fig. 7.

3 - Concluding remarks.

The technique of ionospheric observation based on the ground backscatter sounding seems to be a rather reliable and a simple means to follow, on a large scale, the evolution of the ionospheric disturbances and, more generally, of the ionospheric phenomena.

The interesting modification observed, during an ionospheric storm, in the ionospheric zone being out of the one of decreased electron density, requires undoubtedly a further study.

4 - Acknowledgements.

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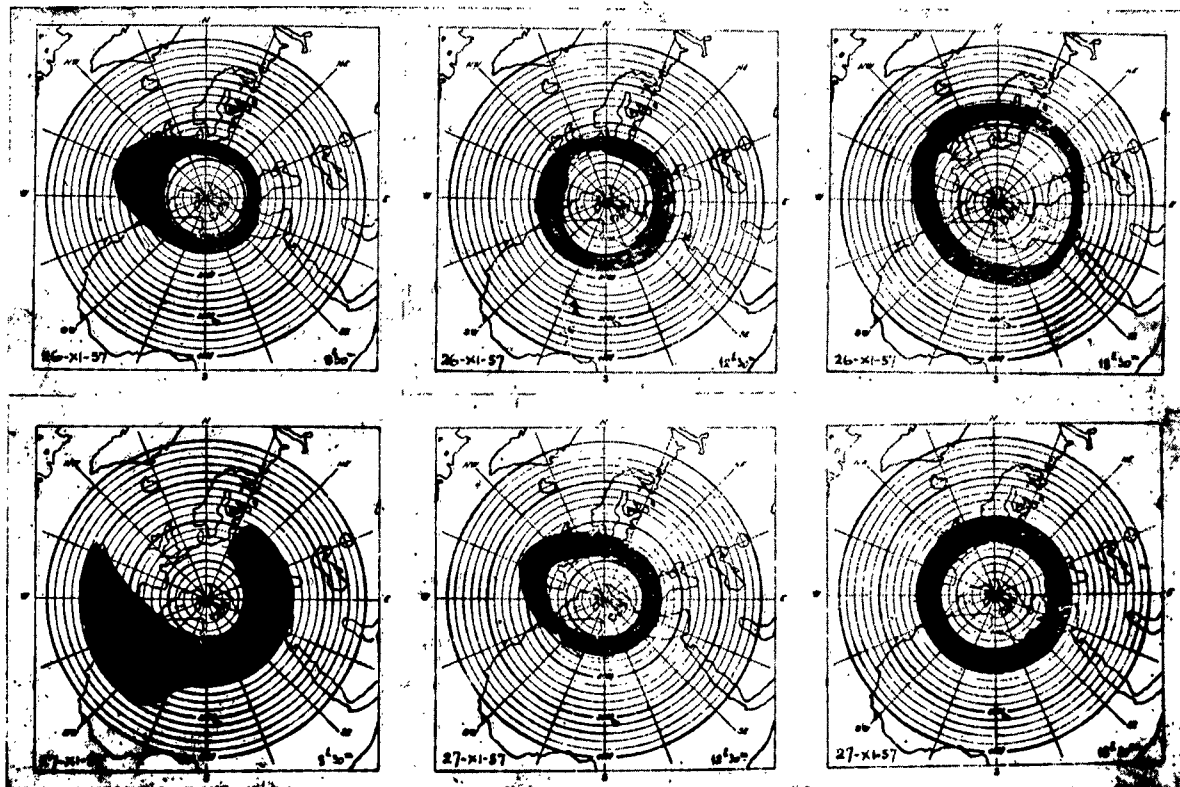


Fig. 5

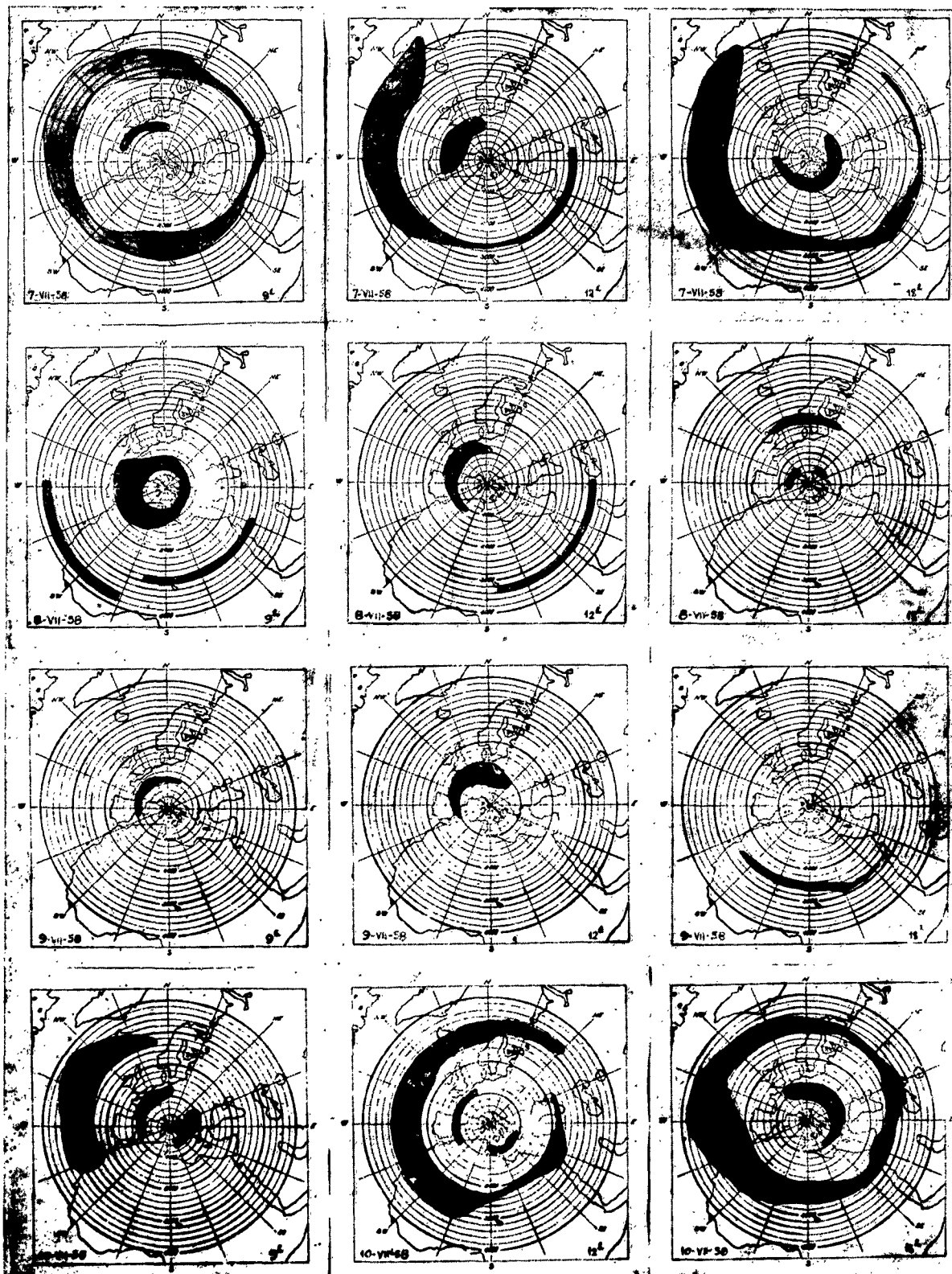


Fig. 6

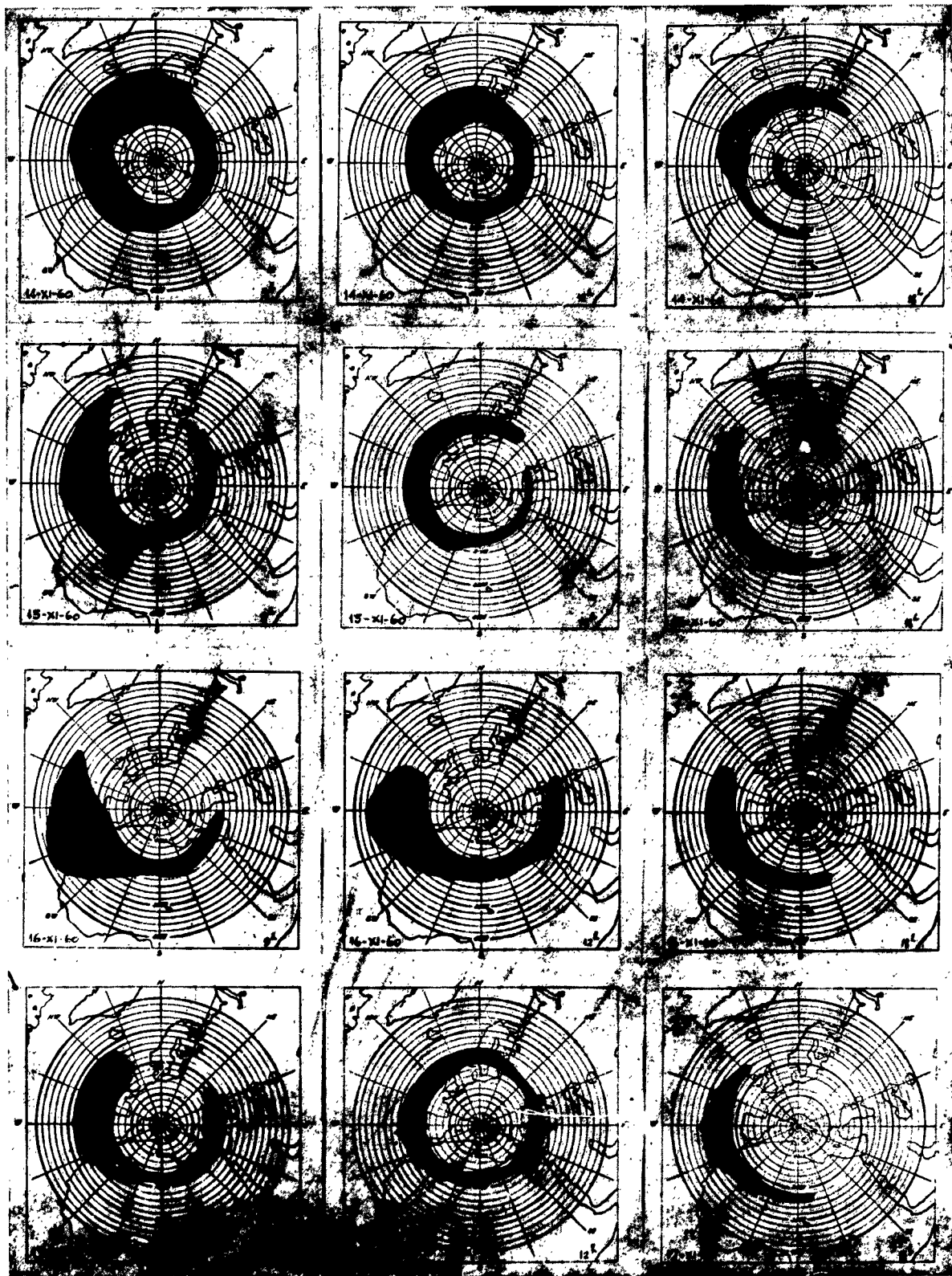


Fig. 7

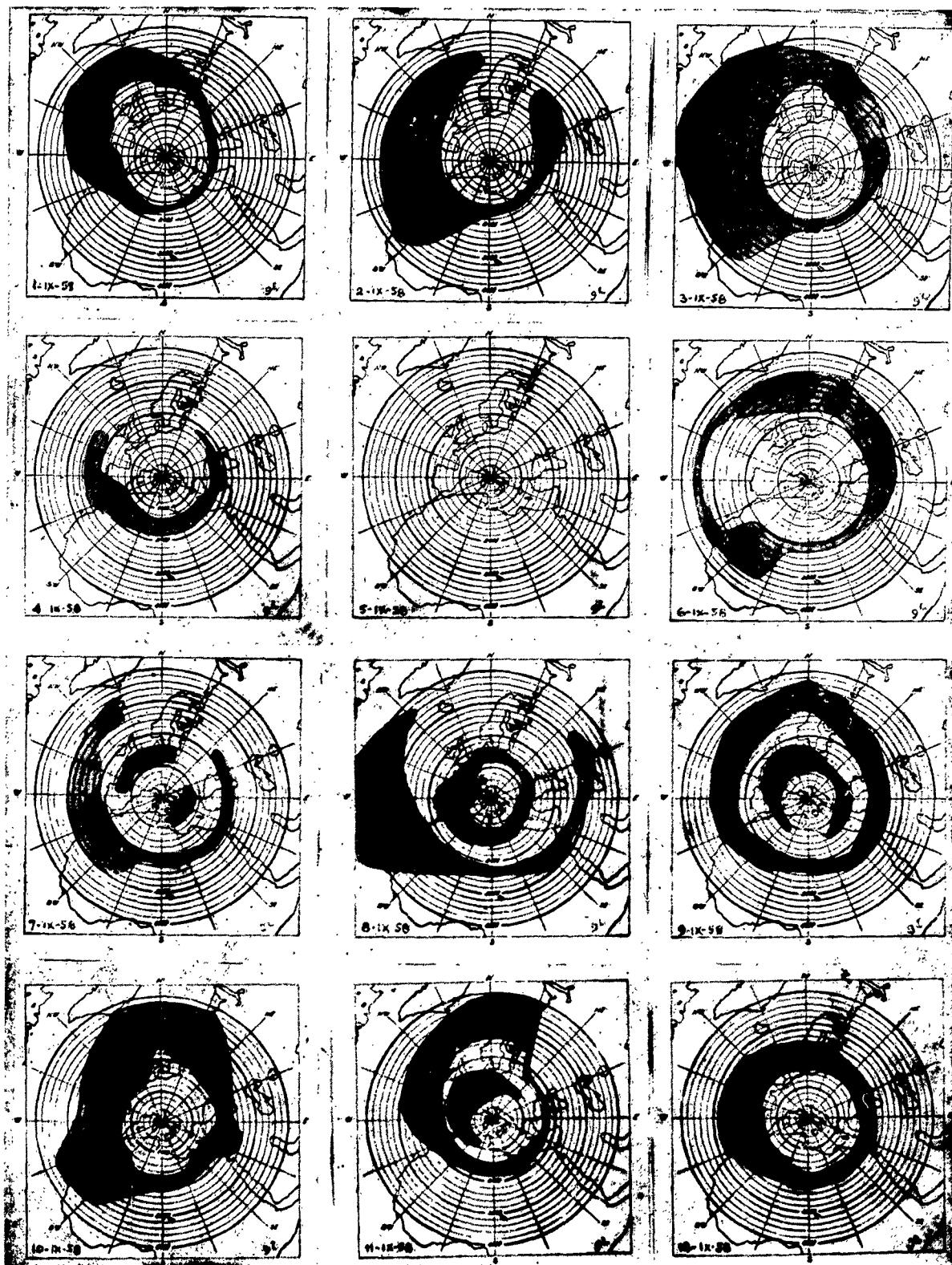


Fig. 8

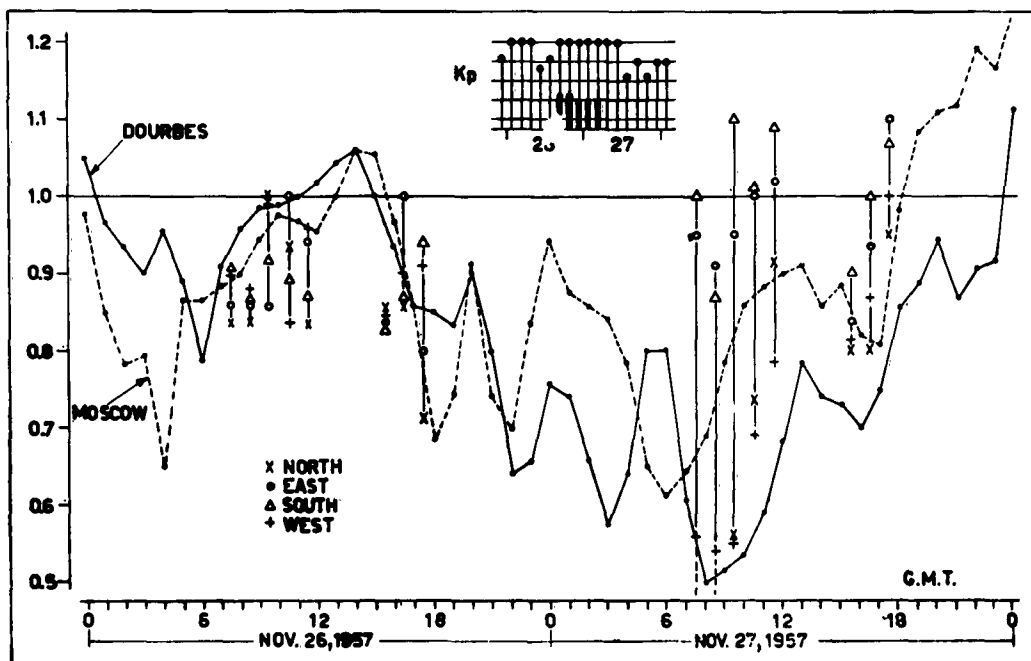


Fig. 9

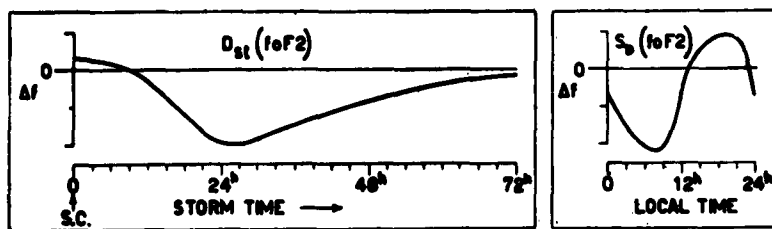


Fig. 10 - Idealized behaviour of $D_{st}(foF2)$ and $S_d(foF2)$ during a storm occurring at a middle magnetic latitude

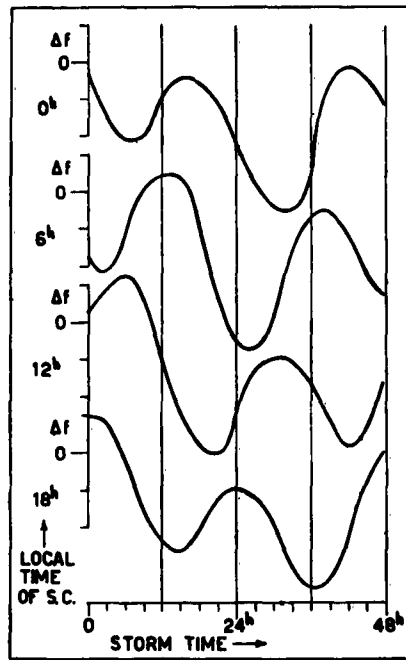


Fig. 11 - Idealized behaviour of Δf_{F2} during a storm occurring at a middle magnetic latitude, for various local times of the magnetic S.C.

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